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HULLS (JONATHAN) A Description and Draught of a new invented Machine for carrying Vessels or Ships out of or into any Harbour, Port, or River, against Wind and Tide, or in a Calm, *large folding plate, morocco extra, gilt edges, by Bedford,* FINE COPY

12mo. *Lond., for the Author,* 1737

EXCESSIVELY RARE and interesting. The author's scheme is believed to be the first published proposal for the propulsion of a vessel by the aid of the paddle wheel. The frontispiece exhibits parts of his apparatus, and also represents a large ship being towed along by the proposed steam tug. The author states on the title that his invention had been made the subject of a patent; and in the body of the work, the motive power proposed is that of the steam engine, on Newcomen's principle. No other copy of this interesting piece is known to have occurred for sale.

Institution of Naval Architects,

2, Adam Street,
Adelphi Terrace,
London, W.C. 2.

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Trans. Inst. Naval Arch. -
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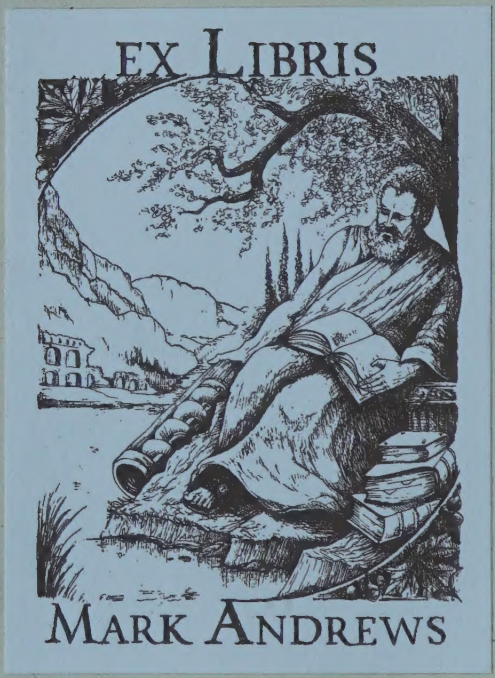
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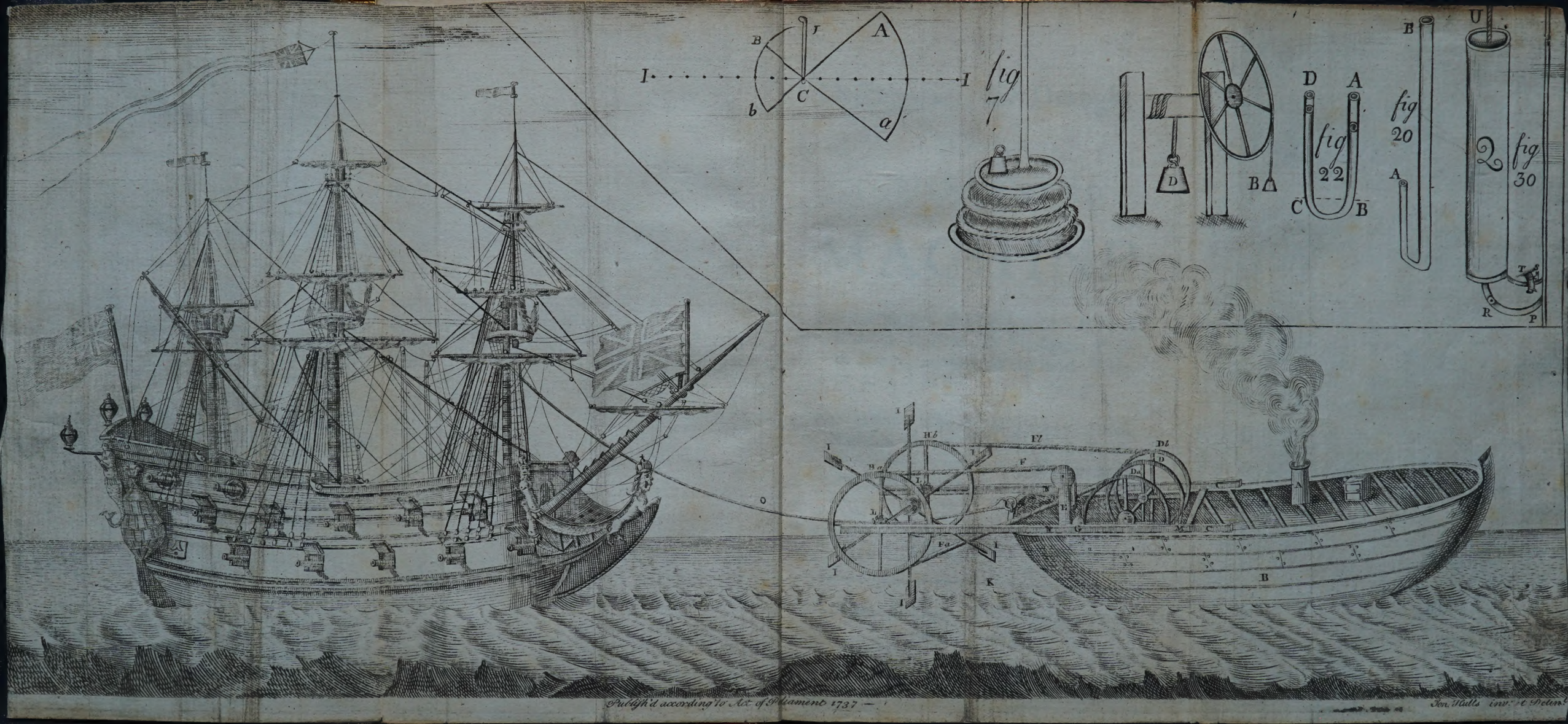

Publish'd according to Act of Parliament 1737 —

Jon. Hulls inv.t & Delin.t

A

Description *and* Draught

OF A

NEW-INVENTED

MACHINE

For carrying VESSELS or SHIPS Out of, or Into any Harbour, Port, or River, againſt Wind and Tide, or in a Calm.

For which, His Majeſty has Granted Letters Patent, for the Sole Benefit of the Author, for the Space of Fourteen Years.

By *Jonathan Hulls.*

London: Printed for the Author, 1737.
(Price Six-pence.)

AN

ABSTRACT

Of the PATENT granted to *Jonathan Hulls* for his new *Machine*.

GEORGE the Second, by the Grace of God, of *Great Britain*, *France* and *Ireland*, KING, Defender of the Faith, *&c.*

To All to whom these Presents shall come Greeting.

WHEREAS our Trusty and Well-beloved Jonathan Hulls hath by his Petition humbly represented unto Our most dearly beloved Consort the QUEEN, Guardian of the Kingdom, &c. That he hath with much Labour and Study, and at great Expence, Invented and Formed a Machine, for Carrying Ships and Vessels out of, or into any Harbour or River, against Wind and Tide, or in a Calm, which the Petitioner apprehends, may be of great Service to Our

Our Royal Navy, and Merchant Ships, and to Boats, and to other Vessels, passing against the Stream in Navigable Rivers; of which Machine, the Petitioner hath made Oath, That he is the sole Inventor, as by Affidavit to his said Petition annexed appears: But in regard, the Petitioner apprehends he cannot at present safely discover the nature of his Invention, he proposes to describe the same more fully, by an Instrument in Writing, under his Hand and Seal, to be enrolled in our High Court of Chancery, within a Time, for that purpose given, as has been frequently done in Cases of the like Nature, And has humbly prayed Our said most dearly beloved Consort, to grant unto him, his Executors, Administrators and Assigns, Our Letters Patent under the Great Seal, for the sole Use and Benefit of his said Invention, within England, Wales, and Town of Berwick upon Tweed, for the Term of Fourteen Years, according to the Statute, in such Cases, made and provided:

Know

Know ye Therefore, That We of Our special Grace, certain Knowledge and meer Motion, Have given and granted, and by these presents for Us, Our Heirs and Successors, Do give and grant unto the said Jo. Hulls, his Executors &c. Our special Licence, full Power, sole Privilege and Authority, during the Term of Years herein expressed, shall and lawfully may make, use, exercise and vend his said Invention of a Machine for carrying Ships and Vessels out of or into any Harbour or River.

And to the End, ỳ the said Jonathan Hulls, his &c. and every of them may have and enjoy the full Benefit, and sole Use and Exercise of the said Invention, according to Our gracious Intention herein before declared, We do by these presents, for Us, our Heirs and Successors, require and strictly Command all, and every Person or Persons, Bodies politick and corporate, and all other Our Subjects whatsoever, of what Estate, Quality, Degree, Name

or Condition soever they be, within that part of Our Kingdom of Great Britain called England, &c. that neither they, nor any of them at any Time, during the continuance of the said Term, hereby granted, either directly or indirectly, do make use or put in Practice the said Invention, or any part of the same so attained unto, by Jonathan Hulls as aforesaid, nor in any wise Counterfeit, Imitate or Resemble the same, nor shall make or Cause to be made any Addition thereunto, or Subtraction from the same, whereby to pretend himself or themselves the Inventor or Inventors, Devisor or Devisors thereof, without the Licence, Consent or Agreement of the said Jonathan Hulls, his &c. in Writing under his or their Hands and Seals, first had and obtained in that Behalf, upon such Pains and Penalties as can or may be justly inflicted on such Offenders for their Contempt of this our Royal Command, and further to be answerable to the said Jonathan Hulls, his Executors, Administrators and Assigns

accord-

according to Law, for his and their Damages thereby occasioned.

In Witness whereof We have caused these Our Letters to be made Patent. Witness CAROLINE, Queen of *Great Britain*, &c. Guardian of the said Realm, *&c.* At *Westminster* the 21st Day of *December* 1736. in the Tenth Year of our Reign.

By Writ of Privy-Seal.

Cocks.

WHEREAS ſeveral Perſons concern'd in the Navigation have deſired ſome Account of my Invention for carrying Ships Out of and into Harbours, Ports and Rivers, when they have not a fair Wind.

But I could not fully deſcribe this *Machine* without Writing a ſmall Treatiſe of the ſame, in which I ſhall endeavour to Demonſtrate the Poſſibility and Probability of the Matter undertaken.

There is one great Hardſhip lies too commonly upon thoſe, who propoſe to Advance ſome New, tho' uſeful, Scheme for the publick Benefit: The World abounding more in raſh Cenſure than in a candid and unprejudiced Eſtimation of Things, if a Perſon does not Anſwer their Expectation in every Point, inſtead of Friendly Treatment for his good Intentions he too often meets with Ridicule and Contempt.

But I hope that this will not be my Caſe; but that they will form a Judgment

ment of my preſent Undertaking, only from Trial. If it ſhould be ſaid, that I have filled this Tract with Things that are foreign to the Matter propos'd, I Anſwer, There is nothing in it but what is neceſſary to be underſtood by thoſe that deſire to know the Nature of that MACHINE, which I now offer to the World: And I hope, that through the Bleſſing of GOD it may prove Serviceable to my Country.

J. H.

A

Deſcription *and* Draught *&c.*

BEFORE I ſpeak of the *Machine* itſelf, it will be neceſſary to explain the Nature of thoſe Powers that are applied to it.

And Firſt of *Mechanical Powers.*

THE Intent of moſt Mechanical *Machines* is to raiſe great Power or Weight with a ſmall intenſity of Power; or, on the other Hand, to cauſe a Motion to be more Swift, or to continue a Motion a long ſpace of Time by a greater weight or force. But there was never any Inſtrument yet could be made to move a Heavy Body by a Lighter, through equal perpendicular ſpace: If that could be perform'd, the perpetual Motion might be eaſily brought to Perfection; but where Nature contradicts, it is in vain to Attempt.

IT is possible to make a *Machine* to lift up an immense Weight with a small String, or even a Hair; but then we must take Notice, there must be Time and Space in Proportion to the weight of the Body to be so raised; for one general Rule to be observed in *Mechanical Powers* is, When the Spaces gone through are in an inverse *Ratio* of the Intensities the Actions are equal.

DEMONSTRATION.

WE will instance in the Ballance-Beam, a well-known Instrument.

THE action of a Weight to move a Ballance, is by so much greater, as the Point pressed by the Weight is more distant from the Center of the Ballance; and that Action follows the Proportion of the Distance of the said Point from the Center. When the Ballance moves about its Center, the Point B *describes the Arch* B b *whilst the Point* A *describes the Arch* A a, *which is the biggest of the Two; therefore, in that Motion of the Ballance, the Action of the same Weight is different, according to the Point to which it is applied, and it follows the Proportion of the Space gone through by*

Vide, *Gravesands* Introduction to Philosophy.

by that Point, therefore at A *it is as* A a, *and at* B *it is as* B b, *but thoſe Arches are to one another as* C A *to* C B. Fig. 1.

THE Brachia of the Ballance are divided into equal Parts, and one Ounce applied to the Ninth Diviſion from the Center is as powerful as three Ounces at the third Diviſion, and two Ounces at the Sixth Diviſion act as ſtrongly as three at the Fourth, *&c.* A Ballance is ſaid to be in *Æquilibrio* when the Actions of the Weights upon each Brachium to move the Ballance are equal, ſo that they mutually deſtroy each other by the foregoing Experiment. Unequal Weights can *Æquiponderate:* for this it is requiſite, that the Diſtance from the Center be reciprocally as the Weights; in that Caſe, if each Weight be multiplied by its Diſtance, the Products will be equal. On this Principle are *Stillyards* made to weigh with one Weight.

Of the AXIS *in* PERITROCHIO.

THE Power hath the greater Force, the greater the Wheel is; and its Action increaſes in the ſame *Ratio* with the Wheel's Diameter; the Weight reſiſts ſo much

much the leſs as the Diameter of the *Axis* is leſs; and its Reſiſtance is diminiſhed in the ſame *Ratio* as the Diameter of the *Axis*; and that there may be an *Æquilibrium* between the Weight and the Power, it is always Requiſite that the Diameter of the Wheel be to the Diameter of the *Axis* in an Inverſe *Ratio* of the Power to the Weight.

For Example, Suppoſe the Diameter of the *Axis* to be One Foot and the Diameter of the Wheel Six Foot: If the weight D weigh Six Hundred Pounds and the weight at B One Hundred pounds, there will be an *Æquilibrium*, and if it is required to raiſe the weight D, the weight at B muſt deſcend Six Foot, in order to raiſe the weight at D one Foot.

There are many ſorts of *Machines* to raiſe great weight, as the Pulley, *&c.* But they are all grounded on the ſame Principles with theſe already mentioned; for if a great weight is to be raiſed by a ſmall Power, this ſmall Power muſt go thro' the larger Space in Proportion to the inequality of the Power with the weight. *Note*, There ought to be ſome Allowance added to the Power that moves any *Machine* more than the Rules of *Mechanicks* mention, by Reaſon of Friction, which is

more or leſs, according to the Nature of the *Machine*; for the larger a Wheel, *&c.* is, and the leſſer the Axis, the leſſer the Friction will be *& contra.*

But ſince our preſent Purpoſe cannot be compleated by any *Mechanical* Rules only, (Becauſe, there can no Motion be contriv'd to be work'd, by Manual-Operation, to move both with Power and with Swiftneſs ſufficient to Anſwer the intended Work) in order therefore to Drive this *Machine* we are forced to apply the weight of the *Atmoſphere:* The Nature of which I ſhall now Endeavour to Explain.

The *Atmoſphere* being an inviſible Fluid, it will be proper to give ſome Account of Fluids in general.

Of Fluids.

" A Fluid is a Body whoſe parts yield " to any force impreſt, and by yielding " are very eaſily moved one among ano- " ther." Whence it follows that Fluidity ariſes from this, that the Parts do not ſtrongly co-here, and that the Motion is not hindred by any inequality in the Surface of the Parts.

Fluids

Fluids agree in this with ſolid Bodies, *viz.* That they conſiſt of heavy Particles, and have their gravity Proportionable to the Quantity of Matter, in any Poſition of their Parts. From this Gravity it follows, That the Surface of a Fluid contained in a Veſſel, if it be not preſſed from above, or if equally preſs'd (for that makes no Alteration) will become Plain or Flat, and parallel to the *Horizon:* for as the Particles yield to any force impreſs'd, they will be moved by Gravity till at laſt none of them can deſcend any Lower. The Lower Parts ſuſtain the Upper, and are preſſed by them; and this Preſſure is in Proportion to the incumbent Matter; that is, to the Height of the Liquid above the Particle that is preſſed. But as the upper Surface of the Liquid is parallel to the *Horizon*, all the Points of any Surface which you may conceive within the Liquid parallel to the *Horizon* are equally preſs'd.

If therefore in any Part of ſuch a Surface there is a leſſer Preſſure than in other Parts, the Liquid which yields to any Impreſſion will aſcend till the preſſure becomes equal.

Example. Take a Glaſs-Tube open at both Ends, and ſtopping one End with

your Finger, immerſe the other in Water; when the Tube is full of Air, the Water will riſe but to a ſmall Height: If you take away your Finger that the Air that is compreſſed may go Out, the imaginary Surface that you conceive in the Water juſt at the Bottom of the Tube is leſs preſſed, juſt againſt the hole of the Tube, ſo that the Water will riſe up in the Tube till it comes up to the ſame Height with the external Water.

The Preſſure upon the Lower Parts which ariſes from the Gravity of the Super-incumbent Liquid, exerts it ſelf every way, and every way equally.

In Tubes that have a Communication, whether Equal or Unequal, whether Strait, or Oblique, a Fluid riſes to the ſame height, that is, all the Parts of the Upper Surface are in the ſame Horizontal Place.

The modern *Philoſophers* conceive Fluids to conſiſt of Particles ſmall, ſmooth, hard, and ſpherical; according to which Opinion every Particle is of it ſelf ſolid or a fixt Body, and, when conſider'd ſingly, is no Fluid, but becomes ſo, only by being join'd with Particles of the ſame kind.

The more perfect a Fluid is, the more eaſily it will yield to all Impreſſions, and the more eaſily will the parts Coaleſce being

ing ſeparated. Properly ſpeaking there is no perfect Fluid in Nature, by Reaſon of their Attraction; for *Mercury*, the moſt perfect Fluid, is not exempt from it.

Of the Actions of LIQUIDS *againſt the Bottoms and Sides of the Veſſel that contains them.*

As the Preſſure of the Liquids is every way Equal, the Bottom and Sides are preſs'd as much as the neighbouring Parts of the Liquids; therefore this Action increaſes in proportion to the Height of the Liquid, and is every way Equal at the ſame Depth, depending altogether upon the Height, and not at all upon the Quantity of the Liquid, Therefore when the Height of the Liquid and the Bigneſs of the Bottom remain the ſame, the Action upon the Bottom is always Equal, however the ſhape of the Body be changed: In every Caſe the Preſſure ſuſtain'd in the Bottom is equal to the weight of a Column of Water, whoſe Baſe is from the Bottom itſelf, and the Height of the Vertical diſtance of the Upper Surface of the Water from the Bottom of itſelf.

To Explain which, *Take a Cylinder of a certain Baſe that will hold perhaps a*

Gallon. This Veſſel being fill'd, the Bottom will be allow'd to ſuſtain the whole Weight of the Fluid therein contain'd, Gravity acting in a right Line and Perpendicularly. Again, take another Veſſel of equal Height and Baſe partly Cylindrical and partly Flanch'd out, the Top being in the form of the Fruſtrum of a Cone, This Veſſel ſuppoſe will hold two Gallons: Then take a third Veſſel of equal Baſe and but half the Height; to make it, however of equal Height with the other two, let a ſmall Pipe be ſolder'd into the Lid. Let this Veſſel contain in the whole but half a Gallon. If theſe be ſeverally fill'd with a Fluid of the ſame Kind, we ſay that the Bottoms and Sides of each of theſe ſhall be preſſed thereby alike. If the Cylindrical part of our ſecond Veſſel mentioned were continued to the Top, the Fluid thereby incloſed wou'd be juſt in the ſame Circumſtances as that in the Veſſel firſt mention'd; and then the Side Water contained in the conical Part would bear againſt the Cylinder, ſuppoſed to be continued to the Top, as if the Water therein was Frozen, on the one Hand, and bearing againſt the Sides of the conical Part on the other, according to the Height of the Fluid between them con-

contained; imagine then the Continuation of the Cylinder removed, or the Water Frozen therein to Thaw, the Preſſure of the Side-water would lye againſt the Fluid Cylinder it ſelf, which being in all parts of equal Weight and Moment with it ſelf, will be thereby ſuſtained Quiet and Motionleſs in its proper Place, and 'twill be ſupported on the other Side in like manner by the ſloping Sides of the Veſſel, nor would the Weight on the Bottom, or againſt the fixt Cylindric Sides of this Veſſel be at all increaſed by the Alteration propoſed.

It muſt however be admitted, that as there is double the Quantity of Matter by Suppoſition contained in a Veſſel of this Form that was in the Veſſel firſt mentioned; The abſolute Weight together will be Proportionable thereto: but then again it muſt be conſidered, that this increaſe of Weight and Preſſure affect only the ſhelving Sides of the 2d Veſſel. And as theſe by their Diſpoſition become an inclined Plane, they are doubtleſs made to bear the difference of Weight propoſed, which muſt be thereby communicated to, and ſupported by the upright Sides of the Cylindric part whereon they Reſt; but on the Area of the internal Baſe and againſt the Sides of the Cylinder within, no more Weight is laid

laid than barely that of the Height of the Fluid above them.

To prove that the Water in the ſmall Tube, in the Veſſel laſt mentioned preſſeth againſt the Bottom and Sides and Top of the Veſſel according to its Height, we have the following Experiment.

Take two round Boards of about a Foot Diameter, and join them together with Leather, in the manner of Bellows that they may hold Water, and in the Top-moſt Board ſcrew in a ſmall Tube of a conſiderable Length, as 4 *Foot: Set a Weight on the Top of this Veſſel near equal in Weight to a pillar of Water of* 12 *Inches Diameter and* 4 *Foot high, keep pouring Water into this Tube at the Top, and it will raiſe the Weight, notwithſtanding the Water in the Tube is not near ſo heavy as the Weight on this Board, as* Fig. 7. *Or, if you were to fill this Veſſel with Water and lay on more Weight than the Weight of the largeſt Column up to the Top, this Weight would driv the Water out at the Top of the ſmall Tube: For as in Mechanical Inſtruments a heavy Body will force a lighter, a larger ſpace and a light Body by paſſing a larger Space, will raiſe a heavy Body, a ſmall Space; therefore Weights are to their Spaces in an Inverſe*

verſe Ratio *as hath been already demonſtrated.*

Hence it follows that every Drop which is at Reſt endeavours to recede every way with equal Force. If therefore it be preſs'd on one Side it endeavours to recede that way with the ſame Force, becauſe Action and Re-action are equal, and with that very force it will preſs every way.

This is proved by ſeveral Experiments. I ſhall Inſtance in one more.

Fix up a Ballance Beam, and to one End hang a Veſſel of Water partly full, made in a Cylindrical Form, and at the other End hang Weights: Then take ſome ſolid Body in your Hand and immerſe the ſame into the Liquid, not touching the Bottom nor Sides: Then hang on Weights to make an Æquilibrium, the ſolid being immerſed to a certain depth, thoſe Weights will be the weight of the whole Water, were it filled up to the place the Water roſe to when this ſolid was immerſed. Note, *The Gravity of the Solid doth not alter the Caſe in this Experiment.*

Of

Of Solids immerſed in Liquids.

The different Gravity of Bodies whether Solids or Liquids ariſes from this, that they contain a greater or leſs Quantity of Matter in an equal Space.

Definition. I.

The Quantity of Matter in a Body, being conſider'd in Relation to the Space poſſeſs'd by it, is called the Denſity of the Body. A Body is ſaid to have Double or Triple, &c. The Denſity of another Body, when, ſuppoſing their Bulks equal, it contains a Double or Triple, &c. Quantity of Matter.

Definition. II.

A Body is ſaid to be Homogeneous, when it is every where of the ſame Denſity.

Definition. III.

Heterogeneous, when the Denſity is unequal in different parts of the Body.

Definition. IV.

The Gravity of a Body conſider'd with Relation to its Bulk is called the Specifick Gravity of a Body.

The Specifick Gravity is ſaid to be double when under the ſame Bulk the Weight is Double.

Therefore the ſpecifick Gravities and Denſities of Bodies in Homogeneous Bodies are in the ſame Ratio, *and they are to one another as the Weights of equal Bodies in reſpect to their Bulk. If Homogeneous Bodies are of the ſame Weight, their Bulks will be ſo much leſs as their Denſities are greater; and under the ſame Weight the Bulk is diminiſhed in the ſame* Ratio, *in which the Denſity is increaſed; therefore, in that Caſe the Bulks are inverſly as the Denſities.*

On the Specifick Gravity of Bodies.

"Aristotle's Notion of the Elements was, that the Earth and Water were poſitively Heavy, Fire poſitively Light, and Air indifferent as to either. His Followers therefore affirm that the aſcent of Bodies is owing to their poſitive Levity, that of Flame and Smoak for inſtance:

But

But in this they are Miſtaken; for Bodies are only relatively Light or Heavy according as they are compared with others of a different Kind: So that Flame or Smoak aſcend not, becauſe they are really Light, but becauſe they are buoyed up by the Air, which is more Denſe, and in its Nature heavier than they, for Flame in Vacuo will ſoon ſubſide, and Smoak, when the Fuliginous parts thereof become heavier than the Medium round them, will viſibly deſcend: Thus Oyl and Wine do not ſwim on Water becauſe of their own Levity; but becauſe Water is a heavier Fluid, and ſinks in them. In Air moſt Bodies ſink becauſe it is very Light; in Water not ſo many, it being far more Denſe; in Mercury ſcarce any may be totally immerſed from the like Cauſe: for is there any greater Reaſon that Cork ſhould be termed Light becauſe 'twill Swim in Water, than that Iron ſhould be eſteemed ſo becauſe 'twill Swim in Mercury."

In general, therefore, one Body is ſaid to be ſpecifically Heavier or Denſer than another when it contains more Matter, or a greater degree of Weight under the ſame or an equal Bulk, or an equal Degree of Weight in leſs Space or Compaſs: For Inſtance, A Cubick Inch of Gold weighs

ten

Ten Ounces Troy, an equal quantity of Lead hardly Six, of common Water, ſo nething better than half an Ounce, ſo that Gold is about Nineteen, and Lead about Eleven times Denſer or Specifically heavier than Water, and thus of any other.

Specifick Gravity then is Appropriate, or the Gravity Peculiar to any Body, whereby it may be Diſtinguiſhed from Bodies of a different Kind: 'Tis ſometimes, and not improperly call'd Relative or Comparitive Gravity, which to diſtinguiſh it from Abſolute or poſitive Gravity, which laſt increaſes always in Proportion to the Bulk of the Body, weigh'd directly, the other not; abſolutely conſider'd, a Pound of one Thing, is as heavy as a Pound of another, without Regard to what their Specifick Gravity is, but their Relative Gravities or Bulk, for Bulk they are very different.

A Body Specifically heavier than a Fluid will ſink therein, becauſe it weighs more than the Fluid, by it diſplaced, and whoſe Room it takes up; ſo that the Imaginary Surface immediately under the Body being there more preſs'd than by the Water in any other Part, it therefore yields and lets it thro'. But a Body ſpecifically lighter than a Fluid will always riſe therein becauſe it preſſes leſs on the imaginary Surface beneath it than the

Fluid would in whoſe place it is ſubſtituted. Were there any neceſſity of proving this by Experiment, it might be done thus; Take a ſmall Glaſs Bolt-head (which were it Solid and of a Lump wou'd be near three times heavier than Water, but being hollow and full of Air only, 'twill immerſe and Swim,) this may be ſo nicely fill'd with Water by the Stem that at the top of a Jar it may Swim, in the middle it may remain at a Poize, and put beyond that it will Sink.

This will be brought about by the Spring of the Air included therein, which being Compreſſible, will either contract or dilate itſelf, according to the Degree of Preſſure 'tis under: Toward the upper part of the Jar, 'twill be preſſed by little more than the Atmoſphere, toward the middle, by the Atmoſphere and ſome ſhaps of Water, and at the Bot- Water ſtill. In the firſt e Machine cannot be he ſecond, in the laſt; whence

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much preſs'd as in t
cond not ſo much as in the
ne Mouth of the Machine b
op'd, as the Preſſure is increaſed,
Water will be gradually thruſt into it,
aking the whole Specifically more Hea-
and ſo will produce the afore-mention-

ing un-
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The Table of Specifick Gravity.

The Cubick Inch of	Ounces Troy	Ounces Avo.
Fine Gold	10, 3592	11, 3656
Standard Ditto	9, 9626	10, 9304
Quick-Silver	7, 3844	8, 1017
Lead	5, 9840	6, 5539
Fine Silver	5, 8500	6, 4183
Standard Ditto	5, 5567	6, 0965
Rose Copper	4, 7471	5, 2083
Plate Brass	4, 4042	4, 8321
Cast Brass	4, 2724	4, 6303
Steel	4, 1421	4, 5445
Common Iron	4, 0313	4, 4230
Block-Tin	3, 8615	4, 2366
Common Glass	1, 3608	1, 4930
Sea Water	0, 5427	0, 5949
Common Water	0, 5274	0, 5787
Linseed Oyl	0, 4916	0, 5393
Oyl Oliv	0, 4815	0, 5283

See Mr. Clare's Treatise of Fluids.

Of the DENSITIES of LIQUIDS.

Since the Denſities of Bodies are in Proportion to their Gravity, by comparing the Weights of equal Bodies, to diſcover their Denſities. If therefore any Veſſel be exactly filled with a Liquid and that

Liquid be weighed and if you make the ſame Experiment with other Liquids their Weights will be as their Denſities; But as this Method is liable to ſeveral Difficulties in Practice I ſhall not ſpend any Time in explaining it here.

When the Preſſures of two Liquids are equal, the Quantities of matter in Columns that have equal Baſes do not differ, wherefore the Bulks, that is, the heights of the Columns are Inverſely as the Denſities, whence may be deduced the Method of comparing them together.

Experiment I.

Pour Mercury into a Curve Tube A, ſo as to fill the lower part of the Tube from B to C, pour in Water in one Leg from B to E, in the other Leg pour Oyl of Turpintine till both the Surfaces of Mercury B. C. be in the ſame Horizontal Line, and the height of the Oyl be C. D, theſe heights will be as 87 to 100, which is the inverſe Ratio that the Denſity of the Water has to the Denſity of Oyl of Turpentine, and therefore theſe Denſities are to each other as 100 to 87. The Mercury is poured in, leſt the Liquids ſhould be mix'd in the bottom of the Tube.

The

The Denſities of Liquids are alſo compared together by immerſing a ſolid in them; for if a ſolid Lighter than the Liquids to be compared together be immerſed ſucceſſively into different Liquids, the immerſed parts will be inverſely as the Denſities of the Liquids: for, becauſe the ſame ſolid is made uſe of, the Portions of the different Liquors, which in every caſe would fill the Space taken up by the immerſed part, are of the ſame weight; therefore the Bulks of thoſe Portions, that is the immerſed parts themſelves are inverſely as the Denſities.

Six THEOREMS *extracted out of* ARCHIMEDES's *Tract, entituled* De Incidentibus Aquæ, *very neceſſary for the better Underſtanding of ſeveral Experiments and Concluſions herein contained.*

THEOREM. I.

" The Superficies of every Liquid that " is conſiſtent and ſettled ſhall be of a " ſpherical figure, which figure ſhall have " the ſame Center with that of the Globe " of the whole Earth and Waters.

Theorem. II.

" Solid Magnitudes that being of equal " Mafs with the Liquid are alfo equal " to it in Gravity, being demitted into " the fettled Liquid do fo fubmerfe in " the fame, as that they lye or appear " not at all above the furface of the Li- " quid, nor yet do they fink to the Bot- " tom.

Theorem. III.

" Solid Magnitudes that are Lighter " than the Liquid, being demitted into " the fettled Liquid, will not totally fub- " merfe in the fame, but fome part there- " of will lye or ftay above the Surface of " the Liquid.

Theorem. IV.

" Solid Magnitudes that are Lighter " than the Liquid, being demitted into " the fettled Liquid, will fo far fubmerfe " till a Mafs of Liquor equal to the " part fubmerfed, fhall in Gravity equa- " lize the whole Magnitude.

THEOREM. V.

" Solid Magnitudes Lighter than the
" Liquid, being thruſt into the Liquid,
" are repulſed upwards with a force as
" great as the exceſs of the Gravity of
" a Maſs of Liquor, equal to the Mag-
" nitude above the Gravity of the ſaid
" Magnitude.

THEOREM. VI.

" Solid Magnitudes Heavier than the
" Liquid, being demitted into the ſettled
" Liquid, are born Downwards as far
" as they can deſcend, and ſhall be Ligh-
" ter in the Liquid by the Gravity of
" a Liquid Maſs of the ſame bigneſs with
" the ſolid Magnitude.

Here follow ſome other THEOREMS, *concerning this Matter.*

THEOREM. I.

" If four pieces of Mettals whereof
" the third is of the ſame Kind with the
" firſt, and the fourth of the ſame Kind
" with the ſecond, are Proportional, their
" Gravities or weights ſhall be Propor-
" tional.

THEOREM. II.

" If there be four pieces of Mettal, " whereof the third is of the ſame Kind " with the firſt, and the fourth of the ſame " Kind with the ſecond, and the firſt and " ſecond be of equal greatneſs, and the " third and fourth of equal weight, the " weight of the firſt and ſecond ſhall be " reciprocally Proportional to the Magni- ", tudes of the third and fourth.

THEOREM. III.

" If Spheres of the ſame Matter, are " in Gravity or Weight as the Cubes of " their Diameters, are in Magnitude, & " *contra*.

THEOREM. IV.

" Pieces of Mettal, if they be of equal " Magnitude, have their weights in direct " proportion: But if they be of equal " weight, they have their Magnitudes " in reciprocal Proportion.

To prove that the weight of the Air forces Fluids as it were ſeemingly to hang in a Tube to ſuch a heighth according to the

the Gravity of the Fluid in such Tube; Mercury will be forced about 29 Inches and Water about 31 Foot; and if the Air is drawn out of the Tube no Fluid will rise any higher than to such height as the weight of the Fluid, makes an Equilibrium, with the weight of the Atmosphere.

As Air is proved to have Gravity according to its Denfity, as well as other Fluids, it is easy conceived the nature of its pressing, the Mercury in the Barometer to such a height, it is not because Nature abhors a Vacuum (as some imagine) for if that were the Case, there would be no Vacuum in the top, were the Tube of ever so great a Length.

The Instrument call'd the Barometer, is to find the weight of the Air at such a present Time, and to shew the difference of the weight at different Times; the different Pressure of the Atmosphere may very well supposed to be occasioned by the Alteration of the height, for as in other Fluids, the deeper they are the greater the pressure at the Bottom.

To make this Matter more plain, take this Example. Take a Barometer that is turn'd at the Bottom, (as they now commonly make them) as *Fig.* 20. and join to the Bottom of some Pipe that comes from

from the Top of ſome Edifice, and being fill'd with Water, will drive the Mercury to the Top of the Glaſs-Tube, by reaſon of the weight of the Pillar of Water and Atmoſphere, both preſs on the Mercury, but unſtop the top of the Tube at A, and the Air will preſs equally upon A and B, therefore the Pillar of Mercury gives the weight of the Pillar of Water, only of the ſame bigneſs of the Tube A, for let the Pillar of Water be of what bigneſs ſoever, the Pillar of Mercury Ballances no more than a Pillar of its own bigneſs, for the Reaſons laid down in the 17, 18, 19, *and* 20*th Pages.* And if you add to, or diminiſh from the top of the Tube B, the Mercury will reſpectively riſe or fall one *14th* of the Length added to, or diminiſhed from the Tube B.

Note. The Mercury is to be meaſured from the Horizantal Line from the top of the Mercury in the ſhort End of the Glaſs-Tube: the Water in B will ſtand 14 times as high as the Mercury in A; Therefore if you Meaſure the height of the Mercury, and have recourſe to the Table of Specifick Gravity, you may calculate the height of this Pillar of water and the weight of the ſame.

Again,

Again, if you were to take a Barometer of 5 or 6 Foot Long and fill it with Mercury and Immerſe the open End into a Ciſtern of the ſame, the Mercury will ſink down out of the Tube into the Ciſtern untill the height of the Mercury in the Tube is about the height of 29 or 30 Inches (according to the weight of the Atmoſphere at that Time) then if you immerſe this Inſtrument in Water, the Mercury will riſe one Inch for the Inſtrument's ſinking fourteen.

If you take two Tubes and join them together, ſo that they ſhall have a Communication at the Bottom by a ſmall Hole, put ſome Mercury into one of the Tubes, and it will riſe to an equal height in both, then pour in Water into either until this Water has driven out all the Mercury into one Tube, and then ſtop; and you'll find the Water to ſtand about 14 Times as high as the Mercury, becauſe they Æquiponderate at thoſe heights.

It may be obſerved what an exact Equilibrium is made by Fluids; for, if you diſturb the Mercury in the Ciſtern wherein the Barometer is immerſed, you will ſee the Mercury act in the Tube in the ſame manner as a nice Ballancé-Beam that Equiponderates.

If you take a Tube of a conſiderable Length, and put a Quantity of Mercury in, ſtop it at the Lower-end, and immerſe it in Water 14 Times as deep as the length of the Mercury in the Tube, and then unſtop the Lower-end, the Mercury will not fall out, notwithſtanding the Tube is open at both Ends: If the Tube is immerſed deeper, the Mercury will riſe higher in the Tube; which Demonſtrates that Fluids are preſs'd upwards as well as downwards, (in Proportion to the height of the Fluid above, and the Gravity of the ſame.

Now Air having a Property in it which other Fluids have not, I mean the Elaſtic-ſpring which renders it Heterogeneous; therefore it is in vain to attempt to Meaſure the height of the Atmoſphere as we do the height of other Fluids, for we may ſuppoſe it to be leſs denſe higher in the Air than it is near the Earth; but a Pillar of this Air of any bigneſs is eaſily weigh'd; as for Example,

We will ſuppoſe a Pillar of Air of 12 Inches Diameter, ſquare the Diameter, and multiply that Sum by 11, and divide it by 14, gives the Area pretty near, than multiply that Sum by 29, the height of the Pillar of Mercury, as will Ballance the Atmoſphere, and you have the con-

tent

tent of cubical Inches of Mercury, then multiply that Sum by the Ounces in a cubical Inch of Mercury, and you have the Ounces in the whole Pillar, which may be brought into Pounds and Hundreds, therefore by this Calculation, a Column of Air of this bigneſs weighs near 15 Hundred weight, and by this Proportion the weight of a Pillar of Air of any Diameter may be found.

The weight of a Pillar of two Foot is near four Times the weight of one that is but one Foot, for the weight is in Proportion to the Squares of their Diameters, or if you ſquare the Diameter and multiply it by 12 it is pretty near the Truth. Reckon the Mercury at 29 Inches, it will be but 1659 pounds which makes it 1728, but this difference ariſes from reckoning the Mercury but 29 Inches, whereas it is ſomething more, except in bad Weather, a Pillar of Air of 20 Inches Diameter will be found to weigh 2 Ton, 2 Hundred, 3 Quarters and 12 Pounds; likewiſe a Pillar of Air of 30 Inches Diameter weighs 4 Ton, 16 Hundred and 20 Pound.

If a Man's Body were to bear the weight of the Atmoſphere in proportion to the ſuperficial content of his Body (as has been imagined) the Strength of his

Bones and Sinews could not ſuſtain it, but if you cut a Hole in the Top of a large Veſſel and then lay your Body on it in ſuch manner as that the Air cannot paſs by you into the Veſſel, and then Pump the Air out of the Veſſel, you will very ſenſibly feel the weight of the Air; for if the Hole is large, you will not be able to ſeparate yourſelf from the Veſſel, but when the Air is let in you are immediately relieved.

Since it is demonſtrated, that the Air is of itſelf of ſuch weight, it may ſeem ſtrange it is not more ſenſibly felt to preſs on human Bodies: The Reaſon is this, there is no Particle in a Man's Body, but is made up with Matter full as heavy as Air, and moſt of the Particles a great deal heavier; therefore every part defends it ſelf within and without, without being preſſed in, for every Body that is heavier than a Fluid being immerſed therein, defends itſelf from external Preſſure: For when you Immerſe a ſoft Body, that is Homogeneous in Water ever ſo deep, if this Body is more Denſe than Water, the Preſſure of the Water will not alter the form of this ſoft Body.

But if a Man were to Dive in the Water very deep, the Water would preſs his Body to a great Degree, notwithſtanding

ſtanding his whole Body is heavier than the Water in the ſame Space: But a Man's Body conſiſting of Heterogeneous Particles and ſome leſs Denſe than Water, thoſe parts leſs Denſe are preſſed in proportion to the height of the Water above him, and not according to the quantity of the Water he is in.

For if a Perſon were to deſcend to the Bottom of a Well full of Water, his Body would be preſs'd the ſame as if he deſcended the ſame Depth into the Sea, for there is the ſame Preſſure againſt a Pool-head as there is againſt the Sea-bank at the ſame Depth, as hath been before demonſtrated.

Thus I have endeavour'd to explain the Nature of the Preſſure of the Air on other Bodies, by comparing it with other Fluids that are Viſible to our Eye, as Mercury, Water, *&c.* and ſince the Preſſure is ſo very great, it is the more fit to be apply'd to a purpoſe wherein all ſorts of manual Operations are Inſufficient. For this preſent Undertaking cannot be ſuppoſed to be done by Strength of Men or Horſes, or by any Machine driven by either.

Laſtly, the Atmoſphere being of a great weight and ſtriving to get in where there

's a Vacuum I ſhall endeavour to ſhew how this Vacuum is made, and in what manner this Force is apply'd to drive the Machine.

In ſome convenient part of the Tow-Boat, there is placed a Veſſel about two 3ds full of Water, with the Top cloſe ſhut, this Veſſel being kept Boiling, rarifies the Water into a Steam, this Steam being convey'd thro' a large Pipe into a Cylindrical Veſſel, and there condens'd, makes a Vacuum, which cauſes the weight of the Atmoſphere to preſs on this Veſſel, and ſo preſſes down a Piſton that is fitted into this Cylindrical Veſſel, in the ſame manner as in Mr. *Newcomens* Engine, with which he raiſes Water by Fire. *See fig.* 30.

P. The Pipe coming from the Furnace to the Cylinder.

Q. the Cylinder wherein the Steam is condenſed.

R. the Valve that ſtops the Steam from coming into the Cylinder, whilſt the Steam within the ſame is condenſed.

S. the Pipe to convey the condenſing Water into the Cylinder.

T. a Cock to let in the condenſing Water when the Cylinder is full of Steam and the Valve *P* is ſhut.

U a Rope fixed to the Piſton that ſlides up and down the Cylinder. *Note.* This Rope *U* is the ſame Rope that goes round the Wheel *D* in the Machine.

It hath been already demonſtrated, that a Veſſel of 30 Inches Diameter, which is but two Foot and a Half, when the Air is driven out, the Atmoſphere will preſs on it to the Weight of 4 Ton 16 Hundred and upwards, when proper Inſtruments for this Work are applied to it, it muſt drive a Veſſel with a great force.

Note. The bigneſs of the Machines may be proportioned to the Work that is to be performed by them; but if ſuch a force as is apply'd in this firſt Eſſay be not ſufficient for any Purpoſe that may be required, there is room to make ſuch Addition as will move an immenſe Weight with tolerable Swiftneſs.

It is my Opinion, it will not be found Practicable to place the Machine here recommended, in the Veſſel itſelf that is to be taken in or out of the Port, *&c.* But rather in a ſeparate Veſſel, for theſe Reaſons:

1. This Machine may be thought Cumberſome and to take up too much Room in a Veſſel laden with Goods, Proviſions, *&c.*

2.

2. If this Machine is put in a ſeparate Veſſel, this Veſſel may lye at any Port, *&c.* to be ready on all Occaſions.

3. A Veſſel of a ſmall Burthen will be ſufficient to carry the Machine to take out a large One.

4. A Veſſel will ſerve for this Purpoſe for many Years, after ſhe is thown off and not ſafe to be taken far Abroad.

The Explanation of the MACHINE.

A, Represents the Chimney coming from the Furnace.

B, The Tow-Boat.

C C, Two pieces of Timber framed together to carry the Machine.

D a, *D* and *D b*, are three Wheels on one Axis to receive the Ropes, *M F b* and *F a*.

Note. *M* is the same Rope that goes into the *Cylinder*, Fig. 30.

H a and *H b* are two Wheels on the same Axis with the Fans *I I I I I I* and move alternately in such a manner, that when the Wheels *D a*, *D* and *D b* move backward or forward they keep the Fans *I I I I I I* in a direct Motion.

F b is a Rope going from *H b* to *D b*, that when the Wheels *D a*, *D* and *D b* move forward, moves the Wheel *H b* forwards, which brings the Fans forward with it.

F a is a Rope going from the Wheel *H a* to the Wheel *D a*, that when the Wheels *D a*, *D* and *D b* move forward the Wheel *H a* draws the Rope *F* and raises

raiſes the weight *G*, at the ſame time as the Wheel *Hb* brings the Fans forward.

When the Weight *G* is ſo raiſed, while the Wheels *D a*, *D* and *D b* are moving backward, the Rope *F a* gives way, and the Power of the weight *G* brings the Wheel *Ha* forward and the Fans with it, ſo that the Fans always keep going forward, notwithſtanding the Wheels *Da*, *D* and *D b* move backwards and forwards as the Piſton moves up and down in the Cylinder.

L L, are Teeth for a catch to drop in from the Axis, and are ſo contrived that they catch in an alternate Manner, to cauſe the Fans to move always forward, for the Wheel *H a* by the power of the weight *G* is performing his Office, while the other Wheel *H b* goes back in order to fetch another Stroke.

Note. The the weight *G* muſt contain but half the weight of the Pillar of Air preſſing on the Piſton, becauſe the weight *G* is raiſed at the ſame time as the Wheel *H b* performs its Office, ſo that it is in effect two Machines

chines acting alternately by the weight of one Pillar of Air of such a Diameter as the Diameter of the *Cylinder* is.

If it should be said, that this is not a New-Invention, because I make use of the same power to drive my Machine that others have made use of, to Drive theirs for other Purposes. I *Answer*, The Application of this power is no more than the Application of any common and know Instrument used in Mechanism for new invented Purposes.

ANSWERS *to some* QUERIES *that have been made, concerning the Possibility and Usefulness of this Undertaking.*

QUERY I.

IS it possible to fix Instruments of sufficient Strength to move so prodigious a Weight, as may be contain'd in a very large Vessel?

Answer. All Mechanicks will allow it is possible to make a Machine to move an immense

menſe Weight, if there is Force enough to drive the ſame, for every Member muſt be made in a proportionable Strength to the intended Work, and properly braced with Laces of Iron, *&c.* ſo that no part can give way or break; if the Braces, *&c* neceſſary for this Work had been put in the Draught, it would have been ſo much crowded with Lines that the main Inſtruments could not be ſo well perceiv'd.

QUERY. II. *Will not the Force of the Waves break any Inſtrument to Pieces that is placed to move in the Water?*

Anſwer. Firſt, It cannot be ſuppoſed, that this Machine will be uſed in a Storm or Tempeſt at Sea, when the Waves are very Raging; for if a Merchant lyeth in a Harbour, *&c.* he would not chooſe to put out to Sea in a Storm if it were poſſible to get out, but rather ſtay untill it is abated.

Secondly, When the Wind comes a Head of the Tow-Boat the Fans will be protected by it from the violence of the Waves, and when the Wind comes Sideways, the Waves will come Edge-ways of the Fans, and therefore ſtrike them with the leſs Force.

Thirdly. There may be pieces of Timber laid to Swim on the Surface of the Water

Water on each Side of the Fans, and ſo contriv'd as they ſhall not touch them, which will protect them from the Force of the Waves.

Up in-land Rivers where the Bottom can poſſible be reach'd, the Fans may be taken out, and Cranks placed at the hind-moſt Axis to ſtrike a Shaft to the Bottom of the River, which will drive the Veſſel forward with the greater Force.

QUERY. III. *It being a continual Expence to keep this Machine at Work, will the Expence be anſwered?*

Anſwer. The work to be done by this Machine will be upon particular Occaſions, when all other means yet found out are wholly Inſufficient: How often does a Merchant wiſh that his Ship were on the Ocean, when if he were there, the Wind wou'd ſerve tolerably well to carry him on his intended Voyage, but does not ſerve at the ſame time to carry him out of the River, *&c.* he happens to be in, which a few Hours work of this Machine wou'd do: Beſides, I know Engines that are driven by the ſame Power, as this is, where materials for the Purpoſe are dearer than in any navigable River in *England*; therefore Experience demonſtrates, that the Expence will be but a Trifle to the

value

value of the Work perform'd by those sort of Machines, which any Person that knows the Nature of those things may easily Calculate.

Thus I have endeavour'd to give a clear and satisfactory Account of my New-invented Machine, for carrying Vessels out of, and into any Port, Harbour or River, against Wind and Tide, or in a Calm; and I doubt not, but whoever shall give himself the Trouble to peruse this Essay, will be so Candid as to excuse or overlook any Imperfections in the diction or manner of writing, considering the Hand it comes from; if what I have imagined, may only appear as plain to others as it has done to me, *viz.* That the Scheme I now offer is Practicable, and if encouraged will be Useful.

FINIS.

Sold by T. Boreman, near *Child's* Coffee-House, in St. *Paul's Church-Yard*; and at the *Pamphlet-Shops*, in *London* and *Westminster*.

1630